X-ray Analysis of the Clay Minerals of the Morrison(?), Twist Gulch and Arapien Formations of central Utah

by

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A senior thesis submitted to fulfill the requirement for the degree of B.S. in Geology, 1981

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ACKNOWLEDGEMENTS

I offer my deepest gratitude to Dr. R. T. Tettenhorst, my advisor and instructor; to Dr. Pride for his assistance with the heavy mineral separations; and to Dr. Moore and Dr. Ehlers for their help with the heavy mineral work.

ABSTRACT

Thirteen samples of siltstones, clays, and shales, one from the Arapien Shale, eight from the Morrison(?) Formation, and four from the Twist Gulch Formation of the Jurassic System of central Utah were collected during the summer of 1982. Both whole rock and clay fractions of each sample were X-rayed. The clay fractions were X-rayed twice; air-dried and after solvation in ethylene glycol. This was done in order to determine the major clay and non-clay mineral constituents. All samples contained quartz. Many also contained calcite, dolomite, and feldspars. Kaolinite was present in most samples. Two Morrison(?) samples exhibited very intense smectite peaks which may indicate a volcanic origin. Both Twist Gulch and Morrison(?) samples contained mixed layer clays (smectite-illite). Thus clay mineral content can not be used to distinguish these formations. The heavy mineral fraction of two Morrison(?) samples was examined microscopically. One sample contained dolomite, hematite, apatite, and zircon. In the second sample hematite, magnetite, leucoxene, zircon, apatite, and tourmaline were identified. The heavy mineral suite did not indicate an exclusively volcanic origin for the latter sample, although other evidence suggested such a possibility.

INTODUCTION

An X-ray analysis of samples from the Arapien, Morrison(?), and Twist Gulch Formations of the Jurassic deposits of central Utah was undertaken in order to determine if clay minerals could be used to distinguish the formations. Also, a study of the heavy minerals in two samples was undertaken in order to determine if any of the strata contained volcanic deposits, undisturbed and/or reworked.

STRATIGRAPHY

The Arapien Shale, the oldest of the Jurassic deposits of central Utah, consists, predominantly, of gray and red fissile shale, with intermittent gray, medium to thin-bedded sandstones. The Arapien Shale which is believed to be of marine origin

(Spieker, 1946), contains abundant bedded salt and gypsum.

Overlying the Arapien Shale is the Twist Gulch Formation which is also Jurassic in age and also is marine in origin. It consists largely of chocolate brown siltstone and sandstone with some white sandstones.

The Morrison(?) Formation overlies the Twist Gulch and is believed to be Jurassic in age. There is some doubt as to its equivalency with the well known dinosaur fossil-bearing Morrison of Colorado and eastern Utah, although it does possess the striking purple, orange, and red hues of the established Morrison. The Morrison(?) of central Utah is composed of massive conglomerates, rich in quartzite cobbles, massive sandstones, mudstones, and local limestone units. The Morrison(?) possesses all the characteristics of, and is believed to be meandering stream, floodplain and minor fresh water lake deposits. The conglomerates indicate a nearby source of coarse sediments, the Sevier highlands.

SAMPLES

Location

Thirteen samples were collected in central Utah in the Sanpete Valley and on the Gunnison Plateau by R. Tettenhorst during the summer of 1982. Ten samples, Jm-82-1 through Ja-82-10, were collected on the road from Wales to Levan on the Gunnison Plateau on July 4th, 1982. Sample localities are shown on a portion of the Nephi quadrangle. (Map 1) Sample #1 was taken from section 12, T.15S.,R.1E. Samples #2-5 were collected in section 11, T.15S.,R.1E. Samples #6-10 were collected in section 2, T.15S.,

R.1E. Samples #11-13 were collected in the Sanpete Valley on July 14, 1982. Sample localities are shown on a portion of the Sterling quadrangle. (Map 2) Samples #11 and 12 were taken from section 27, T.18S.,R.2E. Sample 13 was collected in section 32, T.18S.,R.2E.

Descriptions of Samples

Jm-82-1	Orange siltstone; somewhat muddy and well indurated; no bedding.
Jm-82-2	Hard orange silstone; muddy; no bedding.
Jm-82-3	Orange muddy siltstone; no bedding.
Jm-82-4	Purplish-pink soft mudstone; not fissile.
Jm-82-5	Gray soft mudstone; not fissile.
Jtg-82-6	(Jm)? There was some uncertainty as to which formation this sample came from; chocolate brown somewhat muddy siltstone; no bedding.
Jtg-82-7	Hard chocolate brown sandy bedded silstone; minor clay.
Jtg-82-8	Hard chocolate brown shale; minor silt.
Jtg-82-9	Very soft light brown or buff mudstone; no bedding; silt-rich portions.
Ja-82-10	Hard gray shale; very little silt.
Jm-82-11	Hard whitish gray mudstone; no bedding.
Jm-82-12	Soft green and purple earthy mudstone; no bedding; appears weathered.
Jm-82-13	Soft purple mudstone; not fissile.

ANALYTICAL PROCEDURE

Sample Preparation:Whole Fraction

Approximately 5 grams of each sample were hand ground with a mortar and pestle in order to disaggregate the samples. Oriented mounts were made by placing about 0.2 g of ground sample into a glass vial. An appropriate quantity of deionized water was added to the sample and the mixture was vigorously shaken and then poured onto a glass slide. Care was taken to assure that the coarser part of the sample was not left behind in the vial. The water was then

allowed to evaporate.

Powder mounts were also prepared by filling an aluminim holder, backed by a glass slide, with an adequate quantity of ground sample. Another glass slide was used to pack the mount so that the surface of the sample was flush with the surface of the holder, and to clear away excess sample.

Sample Preparation: Clay Fraction

It was decided not to use the previously ground samples because the coarse particles may have been comminuted by grinding. It was necessary to examine the heavy minerals in the coarse fractions microscopically and unground material was needed for this purpose.

Approximately 5 grams of each sample was placed in 100 ml of deionized water. The samples were permitted to soak in the water and then were gently prodded with a glass rod in order to disaggregate them. The siltier samples, Jm-1 through Jm-3, and the Twist Gulch samples were hard and refused to yield to these efforts so that it was necessary to treat them in an ultrasonic tank for about 10 minutes to further aid in disaggregation.

At this point the samples, now disaggregated, were shaken vigorously and observed for signs of flocculation of the clay particles. Three samples, Jm-82-5, Jm-82-11, and Jm-82-12, did flocculate. This is a difficulty because it leads to departures from Stokes' law which governs settling time. All samples were centrifuged in order to remove soluble salts as these are a factor in producing flocculation. After centrifuging no samples flocculated so

that oriented mounts of the clay fraction could be prepared.

The required settling time to separate the minus 5 micron fraction was determined from Stokes' law (Jackson, 1956).

$$t = \frac{18nh}{g(S_p - S_l)D^2}$$

where,

t = time of fall (seconds)
n = viscosity of fluid (poises)
h = depth of fall (cm)
g = gravitational constant (980 cm/sec^2)
S_p = specific gravity of the particle (gm/cm^3)
S_l = specific gravity of the fluid (gm/cm^3)
D = spherical diameter of the particle (cm)

The following values were assumed to determine the settling time for a 5 micron particle:

n = 0.01 poises
S_p = 2.65 gm/cm^3
S_l = 1.00 gm/cm^3
h = 2 cm
D = 5×10^{-4} cm

Approximately fifteen minutes settling time is the result obtained from this calculation. The samples were shaken and allowed to settle for fifteen minutes. Then, from each sample 5 ml were drawn off from a depth of about 2 cm, and pipetted onto two glass slides; one intended for glycolation and the other simply air-dried. The glycolated samples were exposed to ethylene glycol for at least 72 hours in a closed container. One sample, Jm-82-11, cracked and curled up after air-drying. The second slide of that sample did not curl up but only cracked so it was X-rayed both air-dried and glycolated.

X-RAY ANALYSIS

All samples were X-rayed on a Phillips XRG 3100 generator with a geiger detector, copper radiation, and a nickel filter. Powder and oriented mounts of the whole rock of two samples, Jm-82-1 and Jm-82-12, were X-rayed. Since no significant differences were observed in the two types of patterns, only oriented mounts of the remaining samples were X-rayed. The X-ray equipment had the following settings:

goniometer speed:	1^{o} 2θ/minute
chart speed:	0.5"/minute
voltage:	35 kV
amperage:	15 mA
time constant:	1 second
range:	400 counts/second

Sample Jm-82-13 (glycolated) was X-rayed at 25 kV and 10 mA because at the higher setting the peak at 5^{o} 2θ was very intense, going off the chart from 3^{o} to 6.5^{o} 2θ.

Peaks recorded on the strip chart occured at specific angles of diffraction which were converted to interplanar spacings on the basis of Bragg's law,

$$\lambda = 2d\sin\theta$$

where lamda (λ) equals the wavelength of radiation (taken as 1.54184Å) d is the interplanar distance and theta (θ) is the angle of reflection. The calculated interplanar spacings are utilized to identify the minerals in the samples.

Whole Fraction

The results of the whole fraction analysis are summarized in Table 1. Quartz was detected in every sample. In the siltier samples it was predominant. The major tridymite peak was observed

	Jm 1	Jm 2	Jm 3	Jm 4	Jm 5	Jtg 6	Jtg 7	Jtg 8	Jtg 9	Ja 10	Jm 11	Jm 12	Jm* 13
Quartz	x	x	x	x	x	x	x	x	x	x	x	x	x
Feldspars	x	x		x	x	x	x	x	x			x	
Calcite		x	x		x	x	x	x	x	x	x	x	
Dolomite	x	x	x		x	x	x	x		x	x		
Gypsum	x	x											
Smectite				x	x	x		x			-	x	x
Illite		x				x	x			x			
Kaolinite	x	x	x		x	x	x	x			x	x	

* Jm-82-13 showed the major tridymite(?) peak

Table 1: Whole rock constituents as determined by X-ray diffraction

in sample Jm-82-13 at 20.2° 2θ, although with only one peak the identification is tentative. Tridymite is a high temperature form of silica and occurs in volcanic rocks.

Clay Fraction

Removal of the non-clay constituents and the orientation of the clay particles on the glass slides made the clay peaks more pronounced. The clay minerals were identified by comparing glycolated and air-dried diffraction patterns.

Upon glycolation, the smectite interplanar distance expands in the c-axis direction from about 13Å to about 17Å because of the absorption of the ethylene glycol. The peak in the diffraction pattern migrates from 6.2° 2θ to 5.2° 2θ and becomes sharper and more intense. Mixed layer smectite-illite patterns were broader. Illite was identified by the broad peak at 8.8° 2θ. The peaks were broad because of the interstratification of 10Å illite layers with expandable layers. Mica was identified by the sharpness of the peak at 8.8°. Kaolinite was identified by the sharp peak at 12.3° 2θ. A summary of the clay constituents of each sample appears in Table 2.

RESULTS

Clay Minerals

Smectite-illite mixed-layer clays were found in the siltier Morrison(?) samples and all of the Twist Gulch. Kaolinite was present in most samples and was probably derived from the weathering of silicates and other clays. Very strong smectite peaks were observed in Jm-82-12 and Jm-82-13. Both are purplish clays. The strength of the peaks resembles the pattern obtained from

	Mica	Smectite	Illite	Kaolinite	Mixed-Layer
Jm-1			x	x	x(<.45S)
Jm-2			x	x	x(<.45S)
Jm-3			x	x	
Jm-4			x	x	x(>.6S)
Jm-5			x	x	x(.4-.5S)
Jtg-6	x		x	x(w)	x(.4-.45S)
Jtg-7			x	x(w)	
Jtg-8	x			x(w)	x(.45S)
Jtg-9			x		x(.4S)
Ja-10			x		
Jm-11	x		x	x	
Jm-12		x	x(w)	x	
Jm-13		x			

Table 2: Clay fraction constituents

known volcanic clays. Illite was found in most samples. The degree of interstratification of smectite-illite mixed layers is indicated on Table 2.

Heavy Minerals

Only two samples heavy mineral fraction could be examined because of time constraints. Sample Jm-82-13 was chosen because it had the most intense smectite peak, and was thus considered the most likely to possess the volcanic heavy mineral assemblage. Sample Jm-82-1 was chosen in order to compare one of the siltier, non-smectite rich samples to the first sample.

The heavy mineral fraction was removed from the rest of the sample by first removing the fine fraction by suspending and decanting it and then removing the rest with bromoform on the basis of the density contrast. The fine fraction was suspended in water, and after allowing about a minute for settling the water was decanted. This was repeated until no more material remained in suspension after the minute of settling. The heavy minerals were then segregated from the more abundant lighter material using bromoform with a density of 2.85 gm/cm^3. A separatory funnel was used to remove the particles which fell to the bottom of the bromoform.

Theheavy minerals thus obtained were examined microscopically in order to identify the minerals present and the degree of rounding of those minerals.

A non-opaque heavy mineral suite consisting of biotite, apatite, zircon, and sphene with no tourmaline, garnet, or muscovite would indicate a volcanic origin. (Weaver, 1963) The rounding of the grains provides information about the tranportation of the

sediment. Volcanic sediments which were altered in situ would not be expected to contain any grains that were rounded by transportation.

The heavy fraction of sample Jm-82-1 contained primarily dolomite which was most likely authigenic. Authigenic hematite, zircon and apatite were also present. The zircon and apatite were somewhat rounded. The heavy fraction of sample Jm-82-13 contained much authigenic hematite which had a jagged outline and semi-translucent edges and was red in reflected light. Perfectly euhedral zircon, that had suffered no abrasion was observed. Rounded magnetite and leucoxene, several well rounded grains of tourmaline, and some apatite were also present.

The results of the heavy mineral fraction analysis were inconclusive. Jm-82-13 contained some non-volcanic mineral constituents. It must therefore have undergone some reworking and contamination by intrusive or metamorphic origin.

CONCLUSIONS

The relationship of clay constituents with formation found by Chapman (1981) was not confirmed in this investigation. The Twist Gulch and Morrison(?) Formations can not be reliably distinguished on the basis of clay constituents.

That the Morrison(?) contains some clay layers is suggested by the following evidence: the abundance of smectite in some clay beds with X-ray patterns which resemble known volcanic clays, and the possible occurence of tridymite in Jm-82-13. The heavy mineral evidence is not inconsistent with a volcanic contribution to the Morrison sediments, although non-volcanic sources also contributed.

SUGGESTIONS FOR FURTHER RESEARCH

Studies, both X-ray and heavy mineral, of certain well chosen clay beds in the Morrison(?) might lead to the definite identification of specific volcanic layers in the Morrison(?). Perhaps, some of the material in these beds could be radiodated. A confident establishment of the equivalency of the Morrison(?) of central Utah with the Morrison that outcrops to the east might be possible.

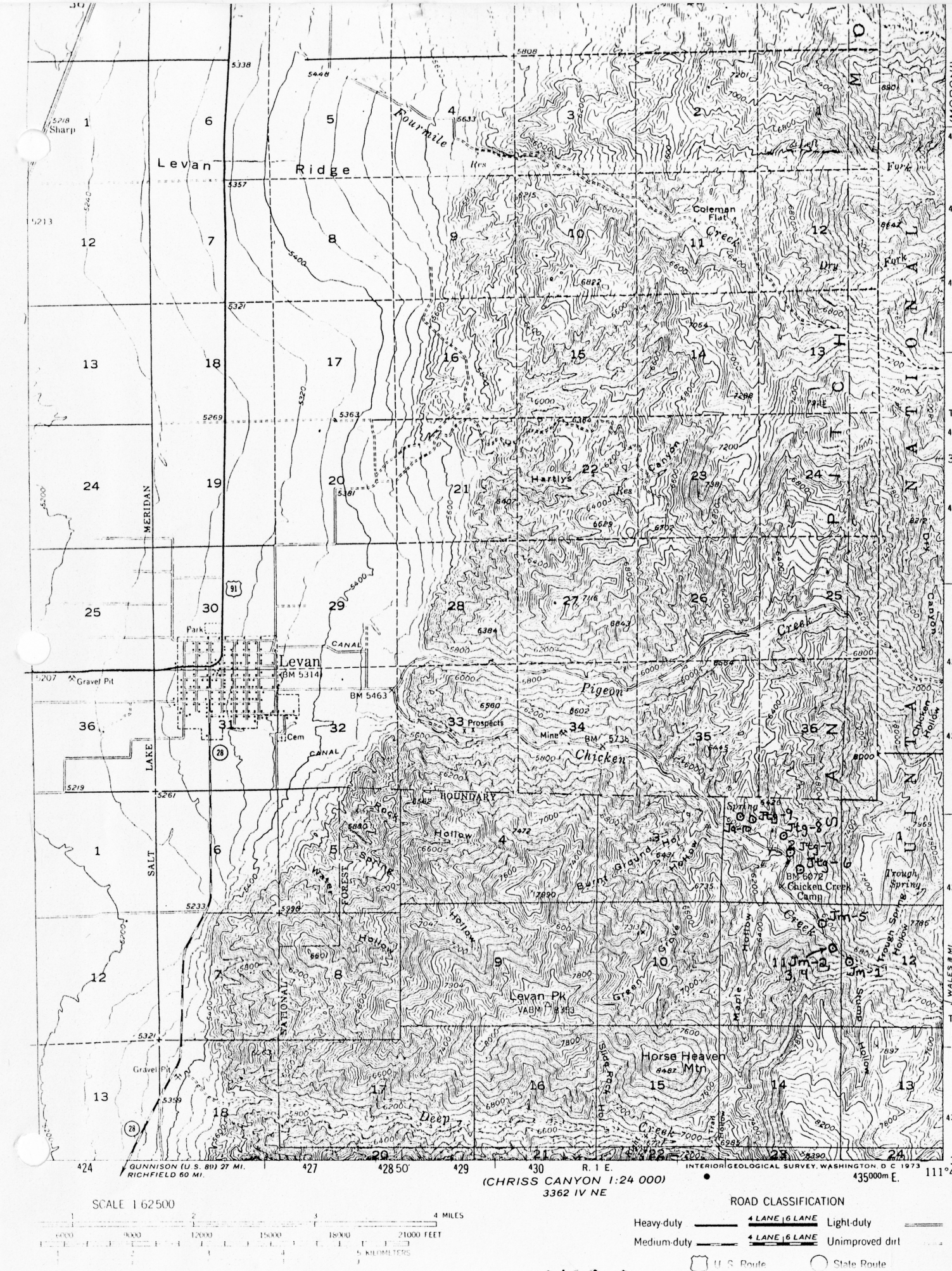
REFERENCES

Hurlbut, C. S.,Cornelis, K., 1977; Manual of Mineralogy-19th edition; Pub. by John Wiley &Sons, New York; p. 418.

Krumbein, W. C., Pettijohn, F. J., 1938; Manual of Sedimentary Petrography, Pub. by D. Appleton-Century Co., New York; pp. 343-344 and pp. 414-495.

Spears, D. A., 1982; The Recognition of Volcanis Clays and the Significance of Heavy Minerals, Clay Minerals Vol. 17 pp. 373-375.

Weaver, C. E., 1963; Interpretive Value of Heavy Minerals from Bentonites, J. Sed. Pet. Vol. 33, pp. 343-349.


Levan
Ridge
Four Mile
Coleman Flat
Creek
Dry Fork
Canyon
Hartleys Res
Pigeon Creek
Chicken Creek
Levan Pk
Horse Heaven Mtn
Deep Creek
Trough Spring
Gravel Pit
Park
CANAL
BOUNDARY
MERIDIAN
SALT LAKE
FOREST
NATIONAL
Sharp
Prospects
Mine
Cem
Spring
Chicken Creek Camp
Jtg-9
Jtg-8
Jtg-7
Jtg-6
Jm-5
Jm-2
Jm-1
T. 14 S.
T. 15 S.
R. 1 E.
91
28
(MORONI) 3663 II
(CHRISS CANYON 1:24 000)
3362 IV NE
GUNNISON (U.S. 89) 27 MI.
RICHFIELD 60 MI.
INTERIOR GEOLOGICAL SURVEY, WASHINGTON, D.C. 1973
SCALE 1:62500
4 MILES
21000 FEET
5 KILOMETERS
ROAD CLASSIFICATION
Heavy-duty
Medium-duty
4 LANE | 6 LANE
Light-duty
Unimproved dirt
U.S. Route
State Route

MAP 1

GUNNISON
RESERVOIR
NORMAL POOL ELEVATION 5378
DENVER
GRANDE
RIO
TREATY
BOUNDARY
Sterling
Creek
Gravel Pit
Quarry
Jm-11
Jm-12
Jm-13
SPILLWAY ELEV 5390
Gaging Station
Flume
Radio Tower
OLD
INDIAN
MOUNTAINS
HOGBACK
VALLEY
21
22
27
28
29
30
31
32
33
34
19
20

MAP 2